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Read page 2. l. *ult. not being so*, p. 10. l. 32. *impose on*, p. 11. l. *antep. precedent to th*[illegible] p. 15. l. 7. *ingeniously*, p. 16. l. 13. *Labra*, p. 17. l. 2. *in different*, l. 3. *Dalgarn*[illegible] l. 37. *tient*[illegible] me t[illegible] *n, t*, p. 19. l. *penult. or as*, p. 22. l. 3. *prevailed with*, p. 23. l. 1[illegible] *knew*, p. 25. l. 2[illegible] *ght not be*, p. 26. l. 25. *renew*, p. 27. l. 36. *years or more*, p. 3[illegible] l. 23. *so too; (at lest of his supervising)* p. 31. l. 39. *owe no more*, p. 32. l. 26. *hath sin*[illegible] Points and Parenthesis omitted or mis-placed, and some literal faults, the Read[illegible] is desired to correct or excuse.

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A DESCRIPTION OF HELIOSCOPES,

And some other

INSTRUMENTS

MADE BY

ROBERT HOOKE,
Fellow of the *Royal Society.*

Hos ego, &c.

Sic vos non vobis——.

LONDON,

Printed by *T. R.* for *John Martyn* Printer to the *Royal Society*, at the *Bell* in St. *Pauls* Church-yard, 1676.

Fig. 1.

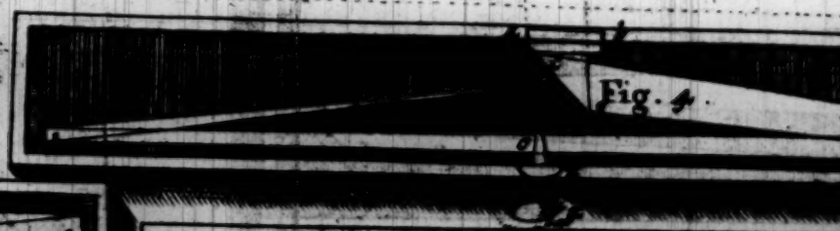


Fig. 4.

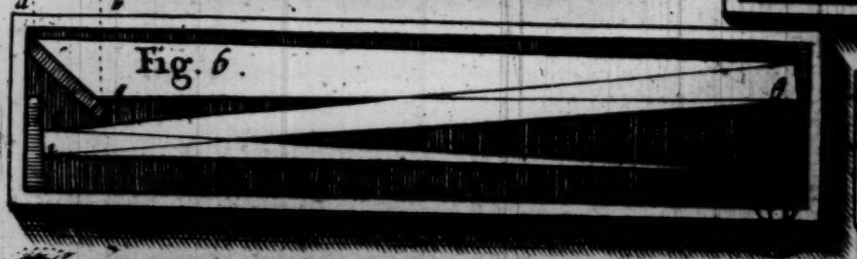
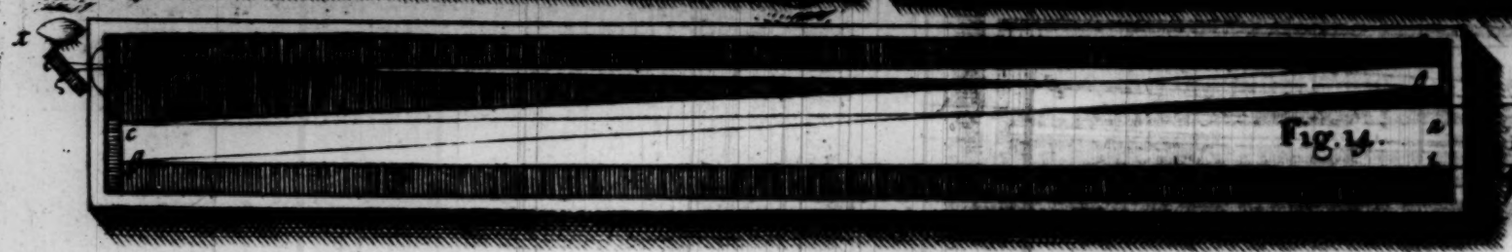


Fig. 6.

Fig. 3.



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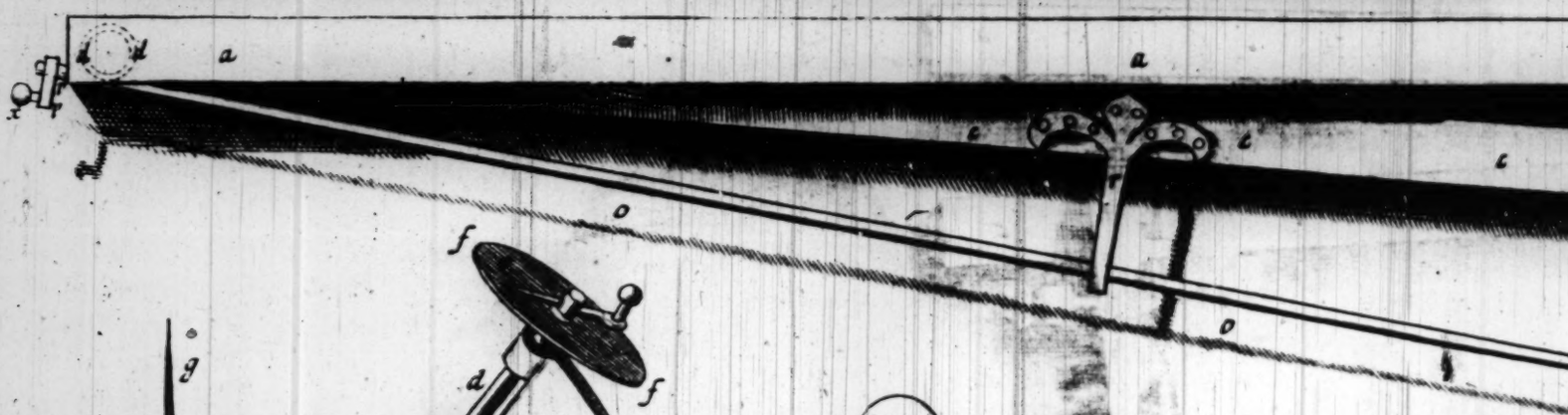

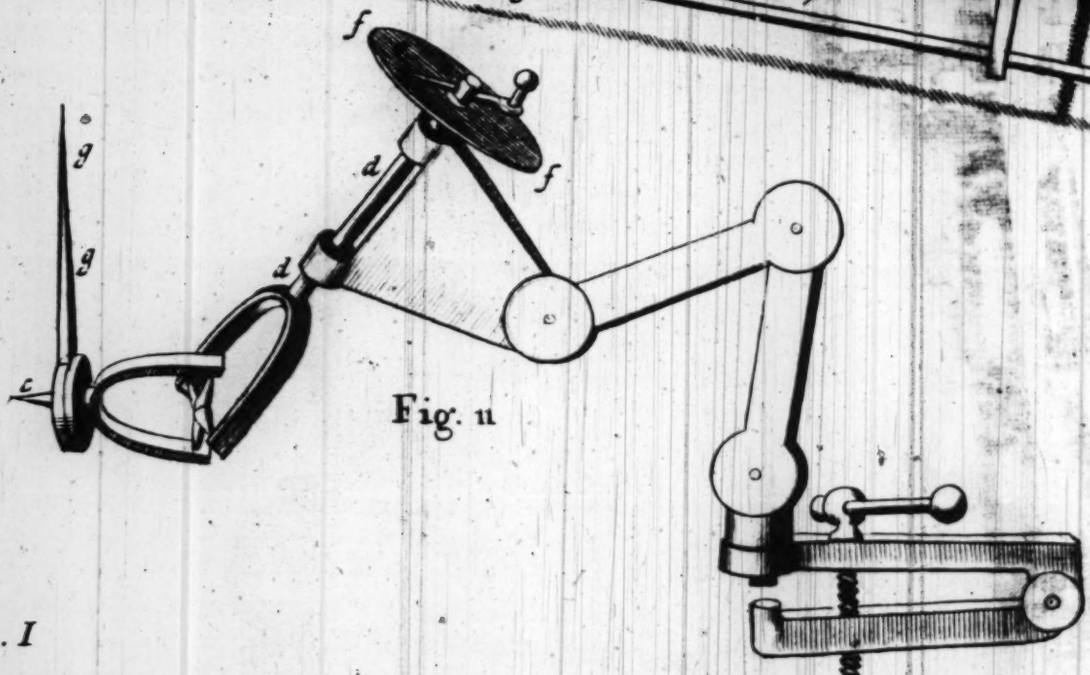

Fig. 11

Fig. 13.

Tab. I

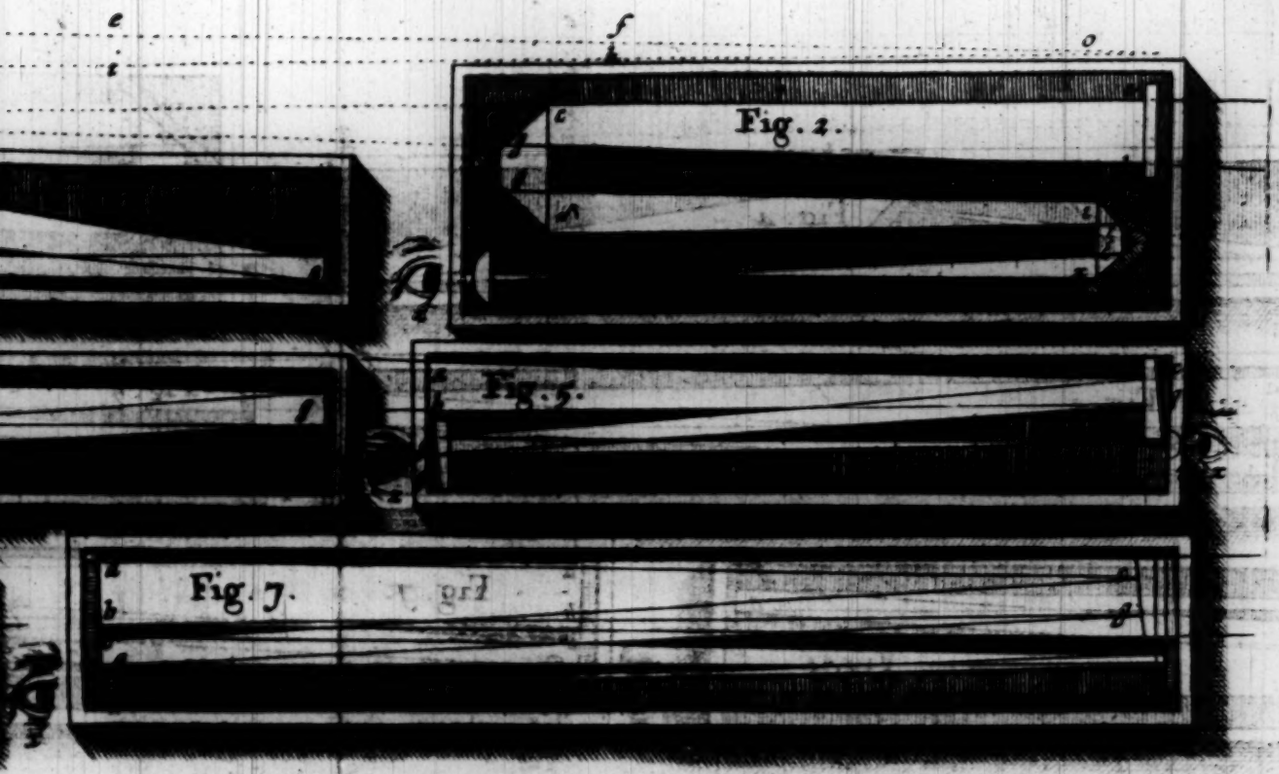
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Fig. 7.

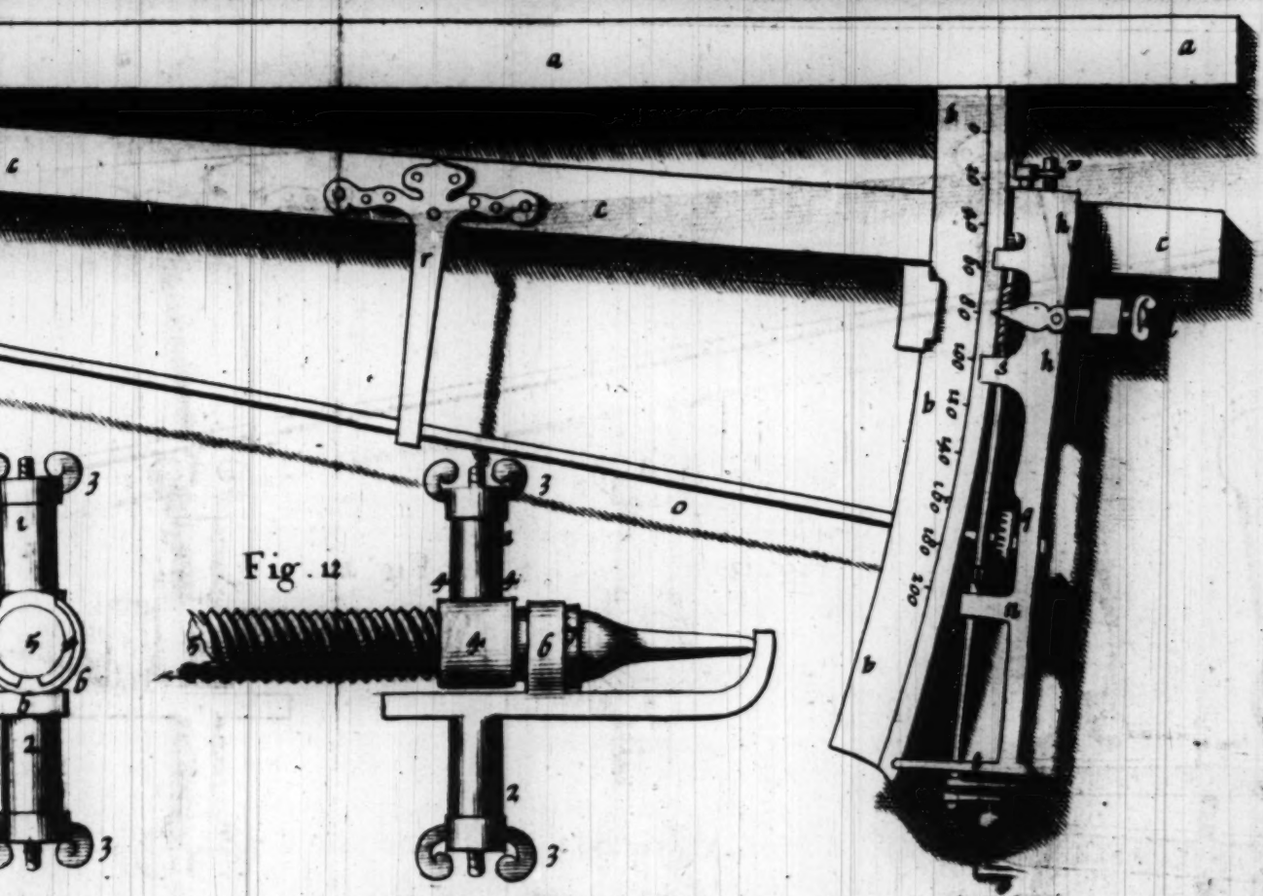


Fig. 12

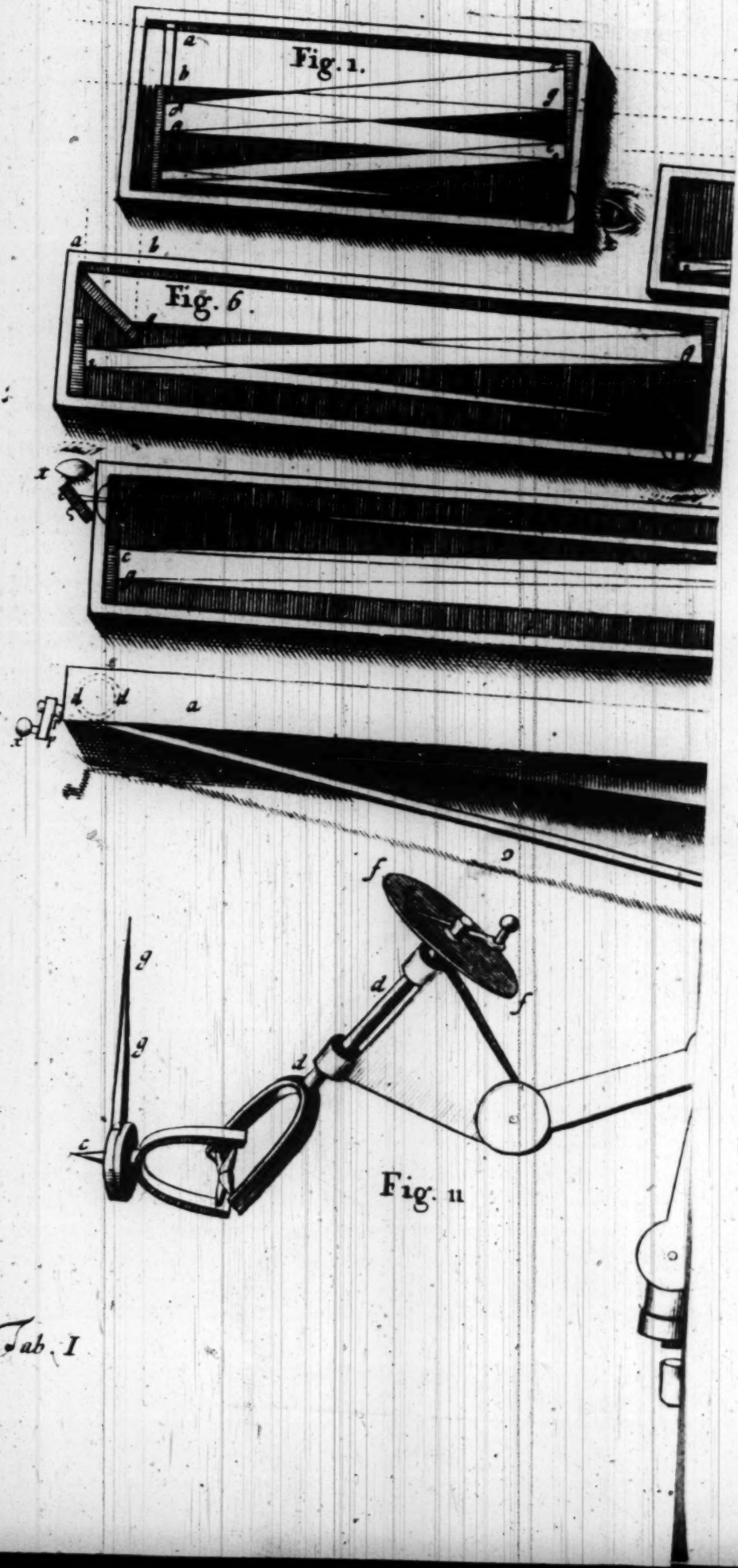


Fig. 11

Tab. I

A DESCRIPTION OF HELIOSCOPES, And ſome other INSTRUMENTS.

THE neceſſary avocations of buſineſs, and the urgent importunity of ſome, for the ſpeedy publication of my Animadverſions, made me conclude them in the Eleventh ſheet, without ſtaying to Explicate ſeveral things which I deſigned to go along with them. But having now retrieved a little more of leaſure, both for *Delineation* and *Deſcription*, for a further eſucidation of what I have ſaid, I ſhall make it my third Attempt, to explain;

Firſt, *A* Helioſcope *to look upon the body of the Sun, without any offence to the Obſervers eye.*

Secondly, *A way of ſhortning reflective and refractive* Teleſcopes.

Thirdly, *A way for uſing a Glaſs of any length, without moving the Tube.*

Fourthly, *An Inſtrument for taking the Diameters of the* Sun, Moon *and* Planets, *or for taking any other Diſtances, to five or ten Degrees, to the certainty of a Second.* Two of theſe I promiſed in the 78*th.* or laſt page of my *Animadverſions*, and the other fall in as analogous to them.

Fifthly, *An Inſtrument for deſcribing all manner of* Dials, *by the tangent projection.*

Sixthly, *The uſes thereof*;

1. *For adjuſting the Hand of a Clock, ſo as to make it move in the ſhadow of a* Dial, *whoſe ſtyle is parallel to the Axis*: Or,
2. *In the Azimuth of any Celeſtial Body*, that is, *in the ſhadow of an upright, or any other way inclining Style, upon any plain.*
3. *For making a Hand move according to the true aquation of Time.*
4. *For making all manner of* Elliptical Dials, *in Mr.* Foſter's *way, &c.*
5. *For communicating a circular motion in a Curve Line, without any ſhaking*: And for divers other excellent purpoſes.

And firſt, *For a HELIOSCOPE which ſhall ſo take off the brightneſs of the Sun, as that the weakeſt eye may look upon it, at any time, without the leaſt offence.* My contrivance is, By often reflecting the Rayes from the ſurfaces of *black Glaſſes*, which are grownd very exactly, flat, and very well poliſhed, ſo to diminiſh the Radiations, that at length they become as weak and faint as thoſe of the Moon in the twilight, ſo that one may with eaſe, and very much pleaſure, view, examine and deſcribe the phaſe of the Sun, and the *macula* and *faculæ* thereof, if any ſuch happen to appear when the Obſervation is made, and it gives a good opportunity of diſcovering them, before we have any advertiſement thereof from others. The reaſon of which will be ſufficiently plain to ſuch as conſider, how great a quantity of the rays of Light

is loſt by every reflection, and that every reflection doth duplicate, triplicate, quadruplicate, quintuplicate, &c. the firſt proportion of loſs. For Inſtance:

Suppoſe I have a *Helioſcope* made of an Object Glaſs, an Eye Glaſs, and four Reflecting Glaſſes, and that, by the firſt reflection, I loſe $\frac{1}{4}$ of the Direct light, I affirm there will remain but $\frac{1}{256}$ part of the Direct rays of the Sun, which can fall upon the eye at the laſt, for if every reflection doth loſe $\frac{3}{4}$ of its Rays, and reflect but $\frac{1}{4}$, and that quarter loſeth $\frac{3}{4}$, and reflects only $\frac{1}{4}$ of its received Light, there will remain but $\frac{1}{16}$ part of the whole, and if this ſixteenth part loſeth three quarters of its Rays, and reflects only a fourth, it will follow, the remainder will only be $\frac{1}{64}$ part of the whole, and if that be once more reflected, the Ray will return but with $\frac{1}{256}$ part of its firſt light.

This, although it be obvious, and eaſie enough now it is known, yet I do not find that any Perſon hath yet had thoughts of applying it to this uſe. The generality of Obſervers have hitherto made uſe of, either ſome very opacous and thick Glaſſes next the Eye, whether of red, green, blew, or purple Glaſs; others have diminiſhed the Radiation, by covering the Glaſſes with a very thick and cloſe coat of the ſoot of a Lamp; others, by caſting the figure upon a piece of white Paper, whence 'tis reflected to the eye; Others have contracted the Aperture into a leſs circle, and thereby let in leſs Light, and ſo make uſe of one ſingle Ray inſtead of a pencil of Rayes; Others have expanded the figure of the Sun, by the help of Eye Glaſſes, into a circle of ten, twenty, or an hundred times its Diameter. But none of all theſe waies do come near this which I now deſcribe by the help of three, four, or more Reflections, as any one upon trial will very plainly diſcover.

Firſt, As to the coloured Glaſſes, I cannot at all approve of them, becauſe they tinge the Rayes into the ſame colour, and conſequently take off the truth of the appearance, as to Colour; beſides, it ſuperinduces a hazineſs and dimneſs upon the Figure, ſo that it doth not appear ſharp and diſtinct. The ſame inconvenience is alſo produced by Monſieur *Hugenius*'s way, of covering the Glaſs with the ſoot of a

Lamp, though not to ſo great a degree. The Figure on paper, or a ſmooth white ſurface is not magnified enough, nor the difference of ſhadows ſo very diſtinct, though that doth very well, if the ſurface be very ſmooth, and the Object be magnified by a Hand Glaſs. That by the contracted Aperture is the worſt of all, by reaſon of a certain propriety of Light not taken notice of yet by Optick Writers, the edges of Objects ſeeming ragged, of which I have hinted ſomewhat in my *Animadverſions*, *pag.* 35, and ſhall ſhortly ſay much more, the whole ground of *Opticks* depending thereon.

The way of expanding the figure of the Sun by the Eye Glaſs, to me ſeems the beſt of all the reſt, but that is apt to vitiate the Figure, to ſuper-induce ſomewhat of Colour, and doth not give the ſmalleſt diſtinctions of lights and ſhadows, without ſomewhat of colour, and ſomewhat of hazineſs and dimneſs.

The Glaſſes of this HELIOSCOPE may be made either by *refracting* or *reflecting* Spherical Glaſſes. The beſt way for taking in a large Angle, is, the uſing refracting Glaſſes, both for the Object and Eye Glaſſes; but the beſt way for taking in a ſmall part, and for avoiding hazineſs, dimneſs, and colours, is, by Reflection, either in part, or in whole; that is, either to make the Object Glaſs only by way of *Reflection*, and the Eye Glaſs by that of *Refraction*, or, both the Object-glaſs and Eye Glaſs alſo by reflection, and to have no refraction at all. The ſeveral waies of doing which I have repreſented in the adjoyning Table, wherein I have expreſſed ten ſeveral waies of placing the ſeveral Glaſſes, ſo as to be fit for the uſe deſigned.

The firſt way repreſented in the firſt Figure, is, a ſixty foot Object-Glaſs, contracted into a twelve foot Tube, by the help of four ſeveral Reflecting-plates placed between the Object-Glaſs and Eye-Glaſs. The Experiment of doing which, I produced and ſhewed before the *Royal Society*, at divers of their publick Meetings at *Arundel houſe*, in the year 1668, and it remains upon their Regiſter.

This (as I then ſhewed) would be of exceeding great uſe in all manner of *Perſpectives* and *Teleſcopes*, if we could find a good material that would make the Reflections very ſtrong

and

and full. And that would not be subject to lose its Figure, which all our specular Metals are very apt to do; for, by it, 'twould be possible to contract the Tubes for long Glasses into very short lengths, and so make them of easie use and manage.

This I attempted with several sorts of Metal, made with ♃, ♀, ♂, *Antimony* and *Arsenick*, but most of these compound Mettals I found to be very spongy, and consequently in the last polish to receive, though a very glaring polish, yet such as did much confound the Object by a kind of hazines, especially if *Putty* be used to glase it, and, for this purpose, *Putty* must not in any wise, that I yet know of, be used; it being so very apt to round off the edges of pores or scratches, which does much contribute to the hazines and confusion of the Object.

If I made use of Glasses foil'd with *Quicksilver*, which I found to give much the best *reflection*, yet I found this inconvenience, that a considerable part of the Ray was lost, by the double reflection at the unfoil'd superficies of the Glass. The first from the surface of the Glass before it entred; this, as it weakned the Ray, so mingling with the other reflection that came from the bottom, it created some kind of hazines and confusion, if the two superficies of the Glass were parallel, but if they were not parallel, it superinduced somewhat of Colour, unless it were helped by a contrary refraction in a second Reflecting-glass, after the manner of that which is delineated in the fifth Figure, where let *a b* represent the Object-Glass, *c g* the first Reflecting-plate, whose thinnest side is to *c*, and *d e* the second Reflecting-plate, whose thinnest part is towards *e*, which doth thereby take off the first Refraction of *c g*, and destroy the Colours superinduced by the first. The Ray also was weakned much more from the second reflection it suffered at the unfoil'd superficies of the Glass, from the reflection of the Air, or *æther*, which is much stronger than that of Glass, at its re-entring into the Air. Besides this, I find that the substance of most Glass is so imperfectly mixt, that there is in the very best much of veinyness and inequality of Refraction in the parts thereof, and thence, though

there

there were no visible vein appearing in the body of the Glass, and though both the surfaces thereof were very truly figured and polished, yet there was some kind of dimness superinduced upon the Objects, by the rays passing through those Glasses. But this was not in all, for I found some that did very well answer my expectation, and I am very apt to believe, that if a pot of Glass were made on purpose, by a way I know, the body thereof might be made perfectly clear, uniform, and transparent, without blebs, veins, or sands, which, when I have leasure and opportunity I design to experience farther. But this only by the by, in relation to the shortning the Tubes of Telescopes for the *Moon*, *Planets*, and other Objects, because it is not at all to our present purpose of making a *Helioscope*, where we make use only of the reflection of the first superficies of the Glass, and where our main aim and design, is, the loss of the strength and brightness of the Rays, and not for preserving the strength and briskness of the Rays, or augmenting them. And therefore for this use, the best material I have yet met with, is, black Glass, black Marble, and Glass of *Antimony*. For these substances being very dark and opaque, do reflect but a very small part of the Raies that fall upon it, and none of those that penetrate into it, especially if they be thick; and being of a very hard and permanent substance, are capable of receiving a very curious and exact polish, and qualified sufficiently to retain and keep it, without receiving injury from the Air, or ordinary wiping.

But in the making of these Glasses for Long *Telescopes*, very great care and diligence must be used to make them of a true flat, and so much the more, by how much the nearer they are placed to the Object-Glass, and the further from the Eye-Glass; a little errour at a great distance from the eye being vastly magnified to the eye at that distance, whereas a greater becomes insensible, if it be near the eye. Let *a b*, in the first, represent a sixty foot Glass, whose focus is at *o*; let *a c d e f o*, and *b g h i k o*, represent the two side Rayes of the pencil of light, this Pencil, by the four Reflecting surfaces ($\gamma\nu$, $\delta\theta$, $\varepsilon\iota$, $\zeta\varkappa$) is broken into five shorter lengths ($\varkappa\delta$ answering to *c d*, $\gamma\theta$ to *g h*, $\delta\varepsilon$ to *d e*, $\theta\iota$ to *h i*, $\varepsilon\zeta$ to *e f*, and $\iota\varkappa$ to *i k*, and lastly,

laſtly, ζ o and κ o, to f o and k o) as will be ſufficiently plain to any one that will but conſider the Scheme.

By this way four fifths of the length of the Tube is taken away, which is the moſt that can be taken away by four Reflections, every reflection running the whole length of the Tube, a leſſer part of the length may be taken away in any proportion aſſigned, as in the ſecond contrivance, deſcribed in the ſecond Figure, two thirds are taken off, when the ſame Letters anſwer to the Object-Glaſs, Eye-Glaſs, the flexures of the ſide Rays of the Pencil, and the Reflecting-plates that make thoſe flexures. The third and fourteenth Figures repreſent the Tube ſhortned by two or three reflections, and ſo ſerves to ſhorten the Tube by two thirds only. Theſe are of uſe for a very ſtrong Eye and with a ſmall aperture of the Object-Glaſs, and when the Sun is near the Horizon, or its light is a little diminiſhed, by a Fogg, thin Clouds, or the like.

If it be thought more convenient to have this long Tube to lie alwaies Horizontal, and conſequently, that there ſhould be no need of having a Pole or Engine to raiſe the Tube: It may be framed ſomewhat like that in the fourth Figure, where the ſame Letters anſwer to all the parts above-mentioned, or elſe like that in the ſixth Figure, the Letters of both which being the ſame with the former, will eaſily explain them.

Now in all theſe, and 20 other contrivances of this nature, with one, two, three, or four Reflecting-plates which may be preſently thought of, the ſight is directed exactly at the Sun, ſo that there will be little difficulty of finding it after the Glaſſes are fixt to their due lengths and poſitions.

I explained alſo at the ſame time to the *Royal Society*, at their publick Meeting at *Arundel-houſe*, ſeveral other waies of facilitating the uſe of very long Glaſſes, for other Objects in the heaven, by the help of one Reflecting plate only, and that was by a Tube fixed, either perpendicularly, horizontally, or obliquely, for it mattered not whether as to the ſeeing the Object in any part of the Heaven, ſuppoſing other circumſtances hindred not, and the object could be as eaſily found as by the common *Teleſcopes* of the ſame length. But of theſe elſewhere.

Theſe contrivances with four *Reflections*, may be made uſe

of

of by ſuch whoſe ſight is weak, but ſuch as can endure it ſomewhat brighter, and would ſee the parts more ſtrong, may make uſe of one of three Reflections only, like that of Fig. 14. which doth beſt ſuit my eye.

Next, this *Helioſcope* may be made by *Reflection* only, without any *Refraction*, and that may be done either in the manner of that in the ſeventh Figure, when *a b* repreſents a concave ſurface of a black Glaſs, whoſe focus is *o*, which, for Inſtance, we will ſuppoſe at the diſtance of forty foot, *c d* repreſents a clear plate of Glaſs of two flat ſurfaces, which are made not parallel but a little inclining, ſo as the reflection from that ſide which is furtheſt from the concave may be caſt another way, and not fall at all upon the third Reflecting-plate *ε ζ*, and becauſe the wedg-like form of this tranſparent plate of Glaſs, *c d*, will cauſe a refraction, and conſequently a coloration of the Ray; therefore there muſt be another wedg-like Plate exactly as may be like the former, which at ſome diſtance, as at *m p*, where the reflection will not come to fall upon the Plate, *ε ζ* muſt be ſo fixed that the thinneſt part of this may lie juſt upon the thickeſt part of *c d*, and the thickeſt of this over the thinneſt of that, by which means both the falſe *reflections* and *refractions* will be removed. From *ε ζ* the Rays are reflected to *γ θ*, and from *γ θ* to *o* the focus, and ſo through the lens, *z*, to the eye *x*. This I take to be the beſt by *Reflection*; but it may be twenty other waies contrived, which I ſhall not now ſpend more time in deſcribing, it being ſo eaſie a matter from the conſideration of theſe I have mentioned, to make an hundred other variations of the principle.

To this *Helioſcope* may be fitted Inſtruments for meaſuring the *Maculæ*, *faculæ*, and *Nebulæ*, viſible in the body of the Sun, as alſo the ſpaces paſſed by them in a day, two, three, ten, &c. together with the variation of their Figures and Magnitudes; but the diameter of the body of the Sun will be better taken by the following Inſtrument. And by reaſon that it will be often neceſſary to draw their figures more exactly, the Engine that I have deſcribed in my *Animadverſions*, in the 67, 68, and 69 *pages*, may be made uſe of to keep the *Helioſcope* alwaies directed at the body of the Sun, which will be no ſmall eaſe to an Obſerver, that is to delineate the figures on Paper.

When

When the brightneſs and radiation of the *Moon*, *Venus* or *Jupiter*, do ſomewhat offend the eye, they will preſently loſe their beards and look very diſtinct, if one reflection from glaſs be made uſe of in the *Teleſcope*.

Another Inſtrument I promiſed to deſcribe, is, for taking any ſuch Diameters *tranſits*, or diſtance to the certainty of a ſecond Minute, by which more may be done for the finding the Parallax of the ſuperiour Planets, and the Longitude on the Earth, then hath been ever yet done by all the Inſtruments that have been uſed in the World.

1. This is made exactly, in all particulars like the *Quadrant*, as to its hollow centre, Screwd-limb, Screw-frame, and long Rod to turn the Screw from the Centre; and that the Screw-frame may be kept down the truer, upon the edge of the Limb, there ſhould be made a ſmall Arm to claſp behind the inward limb of the Inſtrument, after the manner repreſented in the *8th. Figure* by *w*, by which means the Screw will be kept cloſe, ſteady, and eaven to the outward edge of the Limb. The Letters in this *8th. Figure* being the ſame with thoſe of the 1 and *11th. Figures* of the *Animadverſions*, and repreſenting the ſame parts, need no further explanation.

2. Inſtead of this Screw upon a circular Limb, a Screw may be made to move upon a ſtraight Limb, or Ruler; the end of which muſt move upon Centres or Rowlers, the centres or axes of which Rowlers muſt be exactly in the ſame line, when both the Perſpective-ſights are adjuſted to the ſame Object, and the diviſions began. The ſame thing may be done by a ſtraight Screw, in the manner of a pair of dividing *Compaſſes*, where the ſame care muſt alſo be had, that the axes of the Rowlers muſt be exactly in the ſame line, and the ſides of the Incompaſſing-ſcrew, being made of ſteel, muſt be made to ſpring about the long Straight-ſcrew; this long Screw muſt be made of ſteel of half an inch of diameter at leaſt, if it be made 18 inches long, and 'twill be beſt to ſcrew it with a ſmall thred, otherwiſe it will be apt to be moved out of a *ſtraight* by ſcrewing a large thred; and the thred, whether greater or leſs, muſt be made by degrees with a pair of cutting-ſtocks, that may be ſet cloſer every time of ſcrewing.

The manner of contriving the Centres and Sockets may be ſeen in the 12 and 13 *Figures*, where the 13 repreſents it in an end-way Proſpect, and the 12 in a lateral or ſide-Proſpect; 1 is the Rowler of the upper Tube, and 2 of the under, 33 the Screws to faſten them in the holes, 44 the incompaſſing or Socket-ſcrew which ſpringeth cloſe to the Cylinder 5, 6 the Cylinderical ſmooth Socket which guides the Cylindrical-ſcrew, ſo as to make its Axis paſs exactly over the center of the Rowler 22, and which, by means of a Ring 7 on the ſcrew, keepeth the pointed-end thereof 8 againſt the ſtay or portance 9; 'tis not difficult how to make a Dividing-plate, and an Hand or Index thereunto, nor how it may be turned from the centre of the two Tubes by a long Rod, as in the *8th. Figure*; nor will it be difficult, after it is known by Obſervation, how many Revolutions, and what part of a Revolution anſwers to five whole degrees, to calculate a Table of *Subtenſes*, which ſhall ſhew what part thereof goeth to make the *ſubtenſe* of every Minute and Second of the ſaid angle.

3. The ſame thing in the year 1665, I performed by a Rowler, rowling upon the limb of the *Quadrant*, by the help of two Wires which were coyled about thoſe Rowlers, and the ends thereof were faſtned upon the limb of the *Quadrant*; for, by a large index on the end of this Rowler, I was able to move the arm of the Inſtrument to any fifth Second of the *Quadrant*, with great eaſe and certainty.

I alſo at the ſame time made another Frame with a ſtraight Screw, which opened to five degrees only, with Tumbrels or Rowlers like a pair of dividing *Compaſſes* (after the ſame manner with this I have newly deſcribed, for taking *Diameters* or *Diſtances* to five degrees) and by the help of very curious Lines drawn upon a ſmooth Glaſs-plate, and Points very curiouſly made at every five degrees on the limb of the *Quadrant*, or Inſtrument on which it was fixt, and the help of a very deep *Plano convex lens*, whoſe plain ſide was turned downwards towards the Plate, and the convex ſide towards the eye, the ſaid Frame was moveable from five degrees to five degrees, upon the whole limb of the *Quadrant* or Inſtrument, by which Inſtrument I could with great eaſe actually and accurate divide an angle into every five Seconds,

and

and consequently take any angle to the accurateness of five Seconds; for, removing the Frame to the next division, less than the Angle desired, and then by the Glass, fixing one of the Arms that had the plate, exactly over the hole or point of division, by the Screw the remaining part of the Angle could be exactly measured.

As to the method of *dividing* any of these, the best way will be to measure upon some Plain 1000, 1500, or 2000 foot in length, by two Rods of twenty foot long a piece, or else by Wires strained with weights, the way of which I shall shortly describe: Beginning from the very centre of the Instrument, and [illegible] the end thereof, to set up so many Deal-boards joyned to the end of each other in a streight line, or else to strain a pretty big Line, which shall cut the measured line of *distance* from the center of the Instrument at Right-angles, and then by a Table of natural *tangents*, according to the *distance* from the centre of the *Quadrant*, put as *Radius*, to set and mark off upon those *Boards* or *Lines* the divisions of Degrees and Minutes, by *Compasses* or *Rules*, as exactly as may be, and mark them accordingly, that the *Degrees* may be distinguished very plainly from the *Minutes*: Then having adjusted the Instrument, so as to see the beginning of those *Divisions* through both the Tubes at once, to set both the *Indices* to *o*, or the beginning of the *divisions*, then keeping the undermost of the two Tubes fixt to the same place, so as still to respect the same point or beginning of the Divisions upon the *Boards* or *Line*, by the help of the Rod to turn the *Screw* or *Rowl*, till you find the upper Tube to respect the first *minute*, and then the first *degree*, and so till you see the last minute of the five whole *degrees*, or whatever Angle else you design it to take in; then (for the first and third way) reckon how many whole Revolutions, and what part of a Revolution goeth to make up that whole Angle, and subdivide the same by a small Table into *Minutes* and *Seconds*, and you will presently find by the Trial, that you will be able to divide to a strange accurateness upon those Boards, by the help of your *Tubes* and *Screw*, even at the distance of 1000, 1500, or 2000 foot, and even almost to equalize the Divisions by your *Compasses*, when at the very Boards. And by this you

may easily examine, whether your Instrument doth make the *sub-divisions* exactly or not, which will be a great confirmation of the certainty and truth of your Instrument. But for the second way, by streight Screws, the Table of Sub-division into *degrees*, *minutes*, and *seconds*, must be proportioned according to the length of *Subtenses* answering to the *Radius*, which is the distance of the centre of the *Rowlers* from the centre of the Instrument.

Now, because in an Instrument of this bigness it will be somewhat troublesome to turn the whole Angle by the help of the *Screw* upon the Limb, which I find also is somewhat troublesome in the Instrument of three foot *Radius*, when the Angle is large, therefore for preventing of that trouble, and to be able immediately to open the Instrument to the *Angle* desired, or very near it. The *Screw l* (in the first *Figure* of my *Animadv.*) at the end of the moveable Arm, is made, by unscrewing, to draw off the long Screw from touching the threds on the Limb, which being done, the Arm is at liberty to be moved to any part of the *Quadrant*, when by returning the Screw *l*, the Screw-frame and Screw is brought down again to take hold of the Threds of the Limb of the Instrument. The only care to be taken in this action, is, that neither the Index *e e* be at all moved out of its posture to the Index-frame *h h*, nor the Index 8 be moved at all about the rod of the Screw 999. It matters not at all though the Screw-rod 999 be turned round or moved, so as it be done by the Rod *o o o*, and the handle thereof *p p*, or by the small handle *x* at the end of the Screw-rod, and that the Index 8 being very stiffly fixt to the said Rod, be moved round with it by the same motion, without varying its position to the Rod; for being again brought down by the return of the Screw *l*, to take hold of the Threds of the Limb, into which it must be steadily guided by hand, the Index *e e* will shew upon the Limb the number of *Threds* or *Revolutions* from the beginning, and the Index 8 will shew what part of a Revolution there is to be joyned to it.

I hope I shall not need to spend time to explicate, how the Centre of these *Tubes* are to be made, nor how the Glasses and Thred-sights are to be fixt, nor need I much to shew, how the *Tubes* may be stiffned to keep them from warping very

much;

much; A ſmall matter of *warping* not creating any ſenſible errour, I am not much concerned to prevent.

If it be deſired to make the *Screw* leſs, and only long enough to ſubtend one whole *degree*, which is enough in Inſtruments of fifty or ſixty foot *Radius*, it may be done by a ſtraight Screw very well, if care be uſed, which will very exactly take *Diameters* and *Tranſits* to a ſingle Second.

Another thing I promiſed further to explain, was, the contrivance of the *Arms* and *Joynt*, mentioned in *page* 73, as a Univerſal Inſtrument for deſcribing all manner of *Dials*. *For adjuſting the Hand of a Clock, ſo as to make it move in the ſhadow of the Style of a Dial*, that is, *in the Plain of the right aſcenſion of any Point, of the Ecliptick, or of the Heaven*; *or* ſecondly, *in the ſhadow of a perpendicular, or inclined Style*: *For dividing and deſcribing all manner of* Ellipſes *in any* Analematical *projection*; and alſo, *For making all manner of Elliptical Dials in Mr.* Foſter's *way*. *For communicating a round motion through any irregularly bent way, without ſhaking or variation*, and the like.

Firſt, The Inſtrument for deſcribing all manner of *Dials* by the *Tangent projection*, muſt be made in this manner, deſcribed in the 11*th*. *Figure*, in which there are two Axes or rods of Wire that are joyned together by a Joynt, which from the applicability of it to, and fitneſs for all kinds of motions and flexures, I call a *Univerſal Joynt*. One of theſe Rods *b b*, is, by the help of a Frame *a a*, placed perpendicularly over the centre of the Dial, the ſharp or pointed end thereof *c* being ſunk into the Centre, about which it is to be moved according as it ſhall be guided by the motion of the ſecond Rod or Axis *d d*. This ſecond Rod or Axis, is, by its Frame, to be moved and ſet ſo as to be parallel to the *Axis* of the World; then the Hand *e e* of this laſt being turned to the hour of Twelve on the Plate *f f*, the Hand of the firſt *g g* will point out upon the Dial-plain, the Meridian or Twelve of Clock Line.

And ſo for deſcribing any manner of *Dial*, you have nothing to do but to find the *Subſtile*, and the altitude of the *Stile* above the Plain, and to put the Axis in its due ſcituation accordingly, that is, parallel to the *Axis* of the Earth, and

then

then by the Plumbet at the end thereof to rectifie the Meridian or Twelve of clock point: For then, by turning round the Axis or Rod *d d* by the handle, till you see the Index *e e* on the Axis to point at those Hours, halfs, quarters, or minutes you have a mind to take notice of in your Dial; by the second Index *g g*, you are directed to the true corresponding point in the Plain of the Dial it self. But in such Dials as are in or near a Polar-plain, it will be convenient to make use of a small Thred to extend from the Cross, till it touch the Plain in the several hours, halfs, quarters, minutes, *&c.* The Arms of the Joynt in this Operation are to be so fixed, that the axis of the Plate may cross the axis of the Rod at right Angles.

The *Universal Joynt* for all these manner of Operations, having not had time to describe the last Exercise, I shall now more particularly explain. It consisteth then of *five* several parts, each of which I shall describe in the 9 and 10 *Fig.*

The two *first* parts are, the Rods and Axes *A* and *B*, on which the Semicircular Arms are fastned, which are to be joyned together so, as that the motion of the one may communicate a motion to the other according to a proportion, which, for distinctions sake, I call *Elliptical* or *Oblique.*

The two *next* parts are, the two Semicircular Arms *C C* and *D D*, which are fastned to the ends of those Rods, which serve to take hold of the four Points of the *Ball*, *Circle*, *Medium*, or *Cross* in the middle, *X*; each of these pair of Arms have two Centre-holes into which the sharp ends of the *Medium* are put, and by which the Elliptical or oblique proportion of Motion, is steadily, exactly, and most easily communicated from the one Rod or Axis to the other. These Centre-holes I call the *Hands.*

The *fifth* and last thing, is, the *Ball*, *Round-plate*, *Cross*, or *Medium X* in the middle, taken hold of by the hands both of one and the other pair of Semicircular Arms, which, for distinctions sake, I henceforth call the *Medium*, and the two Points 11, taken hold of by the Hands of the Axis, I call the *Points*, and the other two Points 22, taken hold of by the second pair of Arms, I call the *Pivots.*

First,

First, for the *Rods*, they may be made of what bigneſs you think fit, according to the uſe for which you deſign the Inſtrument. The only care to be taken in the making of them, is, firſt that they may be exactly Cylindrical in thoſe parts that move in Collers, and ſecondly, that the Axis or middle line of them do cut each other exactly in one point, which point muſt not vary upon any alteration or change of the Joynt by bending the angle they make with each other, more or leſs, nor with the inclination of the Semicircular-arms to any deſired obliquity, nor with the rotation or turning round of the whole Inſtrument. They require therefore a very dexterous, and a very knowing Artiſt, to make them as they ought to be, to perform their motion with exactneſs. Let *a b* then repreſent one of thoſe Rods, and *c d* a ſecond, which are turned exactly cylindrical within the Collers *e f g* and *h*, and theſe Collers are ſo diſpoſed and fixed on ſome frame, that the middle line or axis of both theſe Cylinders may cut each other in the point *e*; if then both their necks and collers be wrought true and exact, the Axis or middle lines of them will alwaies cut each other in the ſame point, howſoever they be turned round within their Collers; nor muſt this point *i* be varied, howſoever thoſe two Axes are inclined to each other, ſo that though *c d* be inflected to *l m*, or *n o*, and ſo make either an obtuſer or acuter Angle, yet the point *i* muſt be the centre of the Medium, where both the Axes concur and cut each other.

Secondly, The *Semicircular-arms* may be made of what bigneſs, thickneſs, or ſtrength, the occaſion for which they are deſigned ſhall require; that is, if they are only to carry the Hand of a Clock in the ſhadow of a Common Dial, whether made after the *Orthographical*, *Stereographical*, or *Horological* projection; or if they are by an Annual motion to ſhew the motion of the Sun in the Ecliptick, or the æquation of Time, a very ſmall ſtrength is ſufficient; but if they are for carrying round a great *Quadrant*, ſuch as that I have heretofore deſcribed, there they muſt be made ſtronger and more ſubſtantial. Care alſo muſt be had, that the inclining the Arms to any angle may not vary the centre of the Ball or Croſs out of the point, where the two Axes cut each other. Both theſe

Arms

Arms are to be made so as to be inclined to any angle; that is, that the Axis of the Medium, taken hold of by the Arms of Iron, may be made to incline to the axis of the Rod, on which they are in any angle desired, and being set to that Angle, to be steadily fixed, which may be done by a pin, screw or wedge; the way I make use of for the *Azimuth*-Instrument, described in the 73 *p.* of my *Animadversions*, is this which is delineated and explained in the 9*th. Fig.*, where *G* represents a socket of Brass, movable cylindrically round about the end or neck *B*, of the Axis or Rod *BB*, the same with *a b*, in the 22 *Fig.* of my *Animadversions*, and fixable in any posture desired, by help of a side-Screw *h*, such as is very commonly made use of for most Instruments that are fixed upon the end of a three legg'd Staff, and is commonly called a *Cylinder* and *Socket*; this Socket of Brass hath a small Rod of Iron, *k*, fixed into it at *k*, which is near the middle of its concave part, through this Rod there is made a small eye or hole, and through that hole a wedge-like pin *m* being thrust, serves to keep the Semicircular Iron-arms *C C*, steady and fixed in any posture they shall be rectified to. The Semicircular-arms *C C*, are to be made of very good Iron, or rather Steel, and to have a channel or grove quite through the middle of one of them, and extending the whole length of a quadrant of a Circle, namely from *n* to *o*, because, according to the variety of occasions, it may be varied to any point between *n* and *o*; and 'tis to be observed, that the Iron-rod *k* must be so far fixed out of the axis of the Socket *g*, as *n* is distant from *i*, or *o* from *p* the middle of the Iron-arms between *i* and *i*, that so when there is occasion, the Centre-hole or hands *i* may be moved to *p* and fastned. At *q* must be made a Joynt in the Semicircular-arms, so that when the end *n* of the Arms is fixed in or near *k*, the other arm *C* may fall back from the point *i*, otherwise the circular motion, in many cases, cannot be continued quite round, and communicated from one Rod to the other, by help of the Medium or Plate *x*. The several pieces of this Joynt, as they are apart and distinct, you may see in the 9*th. Figure*, and as they are joyned all together fit for motion you may see in the *tenth Figure*, to which also the description of every part is adjoyned in words referred to by the help of *Literal marks*, which

which, I hope, will make it ſufficiently plain to any Artiſt to underſtand.

Thirdly, The medium Ball or Croſs *X*, muſt be made of a bigneſs ſuitable to the Arms and Cylinders, and great care muſt be had that all the ends, points, or handles, lie exactly in the ſame plain, and that they be all equally diſtant from their Center, at leaſt, that any two oppoſite ones be ſo made, becauſe it is not abſolutely neceſſary that they ſhould be ſo all four, though in moſt caſes it be beſt; and farther, the Handles or Pivots ought to be exactly round, conical, or cylindrical, and the middle lines of them to cut each other at right angles, or upon a ſquare; and in general, that all things about the ſaid Joynt be ſo contrived and wrought that the Axis of the two Rods may alwaies cut each other in the centre of the medium Croſs or Plate, and that the ſaid Centre, whatever change happens to the Joynt, may alwaies keep exactly in the ſame very point, without any alteration.

The ſhape of this *Medium* may be either, a Croſs whoſe four ends hath each of them a Cylinder, which is the weakeſt way, 'tis deſcribed in the 9 and 10*th*. *Figures* by the Croſs *X*; or ſecondly, it may be made of a thick plate of Braſs, upon the edge of which are fixed four Pivots, which ſerve for the handles of the Iron-arms to take hold of; this is much better than the former, but hath not that ſtrength and ſteadineſs that a large Ball hath, which is the way I moſt approve of, as being ſtrong, ſteady, and handſome; theſe are delineated in the aforeſaid *Figures*, by *X x*, and *X x x*.

If it be an *Elliptical Dial* to be deſcribed by the *Orthographical projection*, the former way for deſcribing *Tangent Dials*, gives the lines that divide the Ellipſis of the *Equinox* in its true proportions: and if you would have the Lines that divide the Ellipſis of either Tropick, or of any other parallel Circle, you muſt rectifie the Semicircular Arms *C C* of the Axis *B B*, to the degree of the declination of that Parallel, and them proceeding as before, you have the Lines which from the aforeſaid Circle divide the Ellipſis of that *Parallel* accordingly. *Perpendiculars* alſo, let fall from the ends of the Croſs 11, give the true Ellipſis in the *Orthographical projection* anſwering to that Parallel.

These *Lines* thus found, are the true *azimuth Lines* of the points or divisions of that Parallel, and are this way traced out exactly, without any trouble of Calculation, which for some purposes, in *Surveying*, *Navigation*, *&c.* are of very great use, as I shall afterwards shew.

The Universality of this Contrivance, for resolving almost all *Spherical Questions*, makes it of very great use in *Navigation*, if it be adapted as it ought to be, especially for the Common Sea-mans use, who, with a very few Rules, will be able immediately to find the *hour*, and *azimuth* of any point in the Heaven, sufficiently accurate for most Observations that can be made at Sea; of which more hereafter.

For making the *Hand* or *Index* of a Clock move in the shadow of the *Style*, made upon the Face of the Dial, and exposed to the Sun, this *Joynt*, being made to joyn the arbor of the Wheel that goeth round in twenty four hours, with the arbor of the hand, performeth it without any other *Wheel* or *Pinion* in the Dial or Face part of the Clock; if the Arbor of the Clock that should have carried the Hand round in twenty four hours, be made to have the same inclination to the plain of the Dial that the Axis hath, whether parallel to the Axis or not, it matters not at all, so that the Hand be rectified accordingly as it ought to be, and that the *Style* of the Dial ariseth from the centre of the Dial, out-through which the Arbor is produced for carrying the Hand, and placed in its Parallel respect to the Axis, as it ought to be for a *Tangent Dial.* For the shadow-Line of the Axis upon the plain of the Dial, being alwaies carried round the centre of a Dial in a plain, which passeth through the *Axis* or *Style*, and maketh equal progressions about it in equal spaces of Time, and unequal progressions upon the Dial-plain, according to the proportion of Inclination, and the whole Revolution being performed in twenty four hours, and the Hand of the Clock upon the Face of the Dial being alwaies moved in a plain which passeth through the Arbor of the Clock, and maketh equal progressions in equal spaces about the said Arbor, but unequal progression about the Centre of the Dial, according to the differing Inclinations: And those Inclinations being both in the Sun-Dial and Clock-Dial the same, it will follow, that the

Hand

Hand of the Clock muſt alwaies move in the ſhadow of the *Style*, if the Hand be once rectified to the true Plain, and the Axis or Arbor make its Revolution as it ought to do in twenty four hours.

If it be further deſired, for the eaſe of taking *Azimuths* and *Altitudes*, that the Arm of the Azimuth quadrant that is once adjuſted to the *Cæleſtial Object*, ſhould, by the aforeſaid Joynt or Inſtrument, be kept alwaies reſpecting and following the ſaid Object in its *Diurnal motion*, it may be very eaſily performed by the help of a ſmall *perpendicular Ruler*, whoſe lower end is Joynted into either of the Arms 1 1, of the circular Plate *X*, in the 22 and 23*d*. *Figure* of my *Animadverſions*, and the upper end joynted into the movable Arm, at the ſame diſtance from the Centre of the Quadrant that the lower end is from the centre of the Plate *X*, and that the centre of the *Quadrant* be ſet exactly perpendicular over the centre of *X*; but then the diviſions by the help of the Screw cannot be made uſe of, becauſe the Clock-work it ſelf is to turn and move the Arm: But it may be done by any *Quadrant*, where the minute Diviſions are performed by the help of *Diagonals*. For the Arms of the Circular-plate 1 1 being alwaies moved in the ſuperficies of the Cone deſcribed, by the radiation from the Cœleſtial Object to the centre of the Plate *X*, that is to ſay, the Line that paſſes through the Centre of the ſaid Plate, and through the two Points 1 1, being alwaies directed to the Cœleſtial Object, if the Arm of the Quadrant be moved perpendicular over it, and parallel to it, that alſo muſt be alwaies directed to it. And hence it may very eaſily be conceived, how the aforeſaid Semicircular Arms may be readily and certainly rectified to any *Cæleſtial Object*; that is, by fixing *Teleſcopes* or Common-ſights upon the Circular-plate, ſo as the Axis of them may be parallel to the Line through 1 1, and looſing the Screw *h* to rectifie it to the Object by the ſight, and then immediately to fix it in the ſaid poſture by the aforeſaid Screw; the Clock-work of the ſaid Inſtrument having been before that put into motion. The reaſon of all which will eaſily appear to any one that throughly conſiders, that all Celeſtial Objects ſeem, by the diurnal motion of the Earth, to move equally from Eaſt to Weſt about the Axis of it, and

would all do exactly so, were they not somewhat varied by their own proper periodical revolutions, which though it doth indeed make a real difference between their velocities about the Axis of the Earth, yet that difference is but small; and the same circular Pendulum will serve both for the *Sun*, *Moon*, *Planets*, and *Stars*, if at least the Pendulum *p*, in the *fifteenth Figure*, be a little lengthened or shortened, by lifting up or letting down the Rod *q q*, in proportion as the Body *k* moves swifter or slower. And 'twill not be difficult to mark upon the Rod *q q*, the appropriated length of the Pendulum for the *Sun*, *Moon*, or *Stars*; but this only by the by.

If in the next place it be desired, that the Hand of the Clock should be alwaies carried round upon the face of the Clock, in the shadow of a Style perpendicular to that plain, by reason that the declination of the Sun daily varieth, the angles of the shadow about that Style varieth also, and consequently the inclination of the plate of the Joynt to the Axis or Arbor must vary also, and that variation must alwaies be the same with the variation of the declination of the Sun, which is twenty waies mechanically performable in Clock-work, so that the motion shall be performed by the Clock-work alone, without touching it with the hand. All the other directions that are requisite to adjust the Clock-work to such a Dial, is, only to make the Arbor of the Clock-work to have the same inclination to the plain of the Dial, that the Axis of the Earth, or a line paralel to it hath; and rectifying the Hand into the true plain of the Axis, or Inclined arbor, the equality of the motion of the Clock-work, according to the diurnal and annual motion of the Sun, we suppose also to be provided for.

If the Hand of the Clock be desired to be moved in the shadow of any other streight Style, howsoever inclined to the plain of the Dial, then must there be another Joynt like the former, added to the end of that Axis which was perpendicular to the plain of the Dial, and all the three Axes must be scituate in respect of the Plain, in which the Hand on the end of the last is to move, that the inclination of the said Axes to each other, may represent the inclination of the Axis to the perpendicular axis of the Plain, and of

that

that perpendicular Axis to the axis of the Style. Or, which is somewhat shorter, and may be made handsome enough, Let the two ends of the Hand represent the two points of the second circular Plate or Globe, extended long enough to reach to the hour Circle, then let the axis of this second Arm be placed in the axis of the inclined Style, and let the axis of equal motion, representing the axis of the diurnal motion of the Earth, be placed with such inclination to it, as the axis of the Earth hath to the oblique Axis or Style of the Dial, and the motion will be most exactly performed mechanically, and according to the truth of Geometry and Calculation.

Now, in all these motions, care must be taken, to provide that the inclination of the *declination* of the Sun from the Equinoctial, be expresst by the ends 11, in the 22 and 23 *Figures* of the *second Plate* of my *Animadversions*, of the Cross, taken hold of by the semicircular arms *c d*, upon the end of the first Axis; that is, that the said arms may, by their revolution, make the line of the Cross describe such a cone about the first Axis, as the motion of the Sun doth about the axis of the Earth, making the centre of the Earth the apex of that Cone; which will be done, if the said semicircular Arms be moved, and set to the declination of the Sun for that day. Or, that an additional motion be added to the first Axis, that the Clock it self may perform it. This may be done twenty waies easily enough, which I suppose will be sufficiently obvious to any knowing Mechanick, and that without the help of Tooth-wheels or Pinions, which in works of this nature are in no wise to be made use of, by reason of their shaking and uncertainty, which I shall elsewhere describe.

There is one only difficulty in this motion, and that is only in such Objects as pass over, or very near the Zenith or Nadir of the place, for in those cases, when the Object comes very near the Zenith, the obliquity of the motion of the one to the other is so very great, that the first Axis doth not move the second without some difficulty: But to remedy this, the expedient is as easie, and that is, by having a little barrel about the perpendicular Arm, to carry it forward as far and as fast as the first Inclined axis will permit it; which weight

may

may be removed as ſoon as the Object is a little way paſt the Zenith.

The next uſe that may be made of this, is, for carrying the Hand of a Clock ſo, as alwaies to move over that point of the Ecliptick in which the Sun is, in a Stereographical projection of the Sphere upon the Plain of the Equinoctial, or in an Orthographical projection of the ſaid Sphere upon the ſame Plain, ſo as to expreſs thereby not only the differing right aſcenſions, but the anomaly alſo of the Suns motion in the excentrick of the Ecliptick. And by this means the Face of the Clock may be made by a Planiſpherical projection, to repreſent the motion of all the *Stars* appearing in any Horizon that is not too near the Equinoctial; their *Riſings*, *ſettings*, *culminatings*, *azimuths*, and *almicanters*; *Riſings* and *ſettings* of the *Sun*, the *lengths* of the *Days* and *Nights*, and of the *Twilights* and *Dawnings*, and many other Problems of the Sphere. And, which is a conſequent of this, it may be made to ſhew the equation of Time, which is neceſſary to be made uſe of for ſetting a pendulum Clock by the Sun, the manner of doing which I muſt refer to another opportunity, as I muſt alſo the uſe of this Joynt, for *drawing Ellipſes*, *drilling* and *boring* of *bending Holes*, for *turning Elliptical* and *Swaſh-work*, till I publiſh my deſcription of a *Turning Engine*, capable to turn all manner of *Conical Lines*, and *Conoeidical*; all manner of *Foliage* and *Flower-work*, all variety of *Basket* or *Breaded-work*, all variety of *Spiral* and *Helical-work*, ſerving for the imitation of the various forms and carvings of all ſorts of *Shells*; for *cylindrical* and *conical Screws*; all variety of *Emboßments* and *Statues*; all variety of *edged* and *Wheel-like work*; all variety of *Regularly ſhaped Bodies*, whether the five Regular bodies of *Plato*, or produced from thoſe by various ſections or additions, of which the variety is infinite; all variety of *bended Cylinders* or *Cones*, and thoſe whether round, in the manner of an *Oxes-horn*, or compreſſed and angular, like thoſe of a *Ram* or *Goat*; for all manner of *Swaſht-work*, *Compreſt-work*, *&c.* every of which principal parts hath a vaſt variety, and the compound and decompound principles have a variety almoſt infinite.

Appen-

Appendix.

Concerning the Eclipſe of the Moon, *obſerved in* London.

JAnuary the firſt, 167$\frac{4}{5}$, being at Sr. *Jonas Mores* in the Tower of *London*, and making uſe of a Teleſcope of eight foot, and my pocket-Watch, whoſe ballance was regulated with ſprings, I obſerved the Eclipſe of the *Moon*, which began at about twenty minutes after five, the penumbra very much cheating the naked eye; for the Penumbra had darkned that ſide of the *Moon*, next the ſpot *Grimaldi*, about half an hour before, and grew darker and darker towards the edge where the *Umbra* entred, ſo that if the light of the *Moon* were diminiſhed either by reflection upon dark Glaſs, or looking through a ſmall hole, between a quarter and a third part of the *Moon* ſeemed eclipſed before the *Umbra* entred; but the Teleſcope diſcovered it plainly to be no true *umbra*, but *penumbra*.

This I note, becauſe ſuch Perſons as do not make uſe of a Teleſcope, but only of their naked eye, are very apt to be much deceived in their eſtimation of the beginning and end of the Eclipſe.

At 5. 48. we judged by the Teleſcope that the *Moon* was eclipſed ſix digits, or half; at 6. 19. the total Eclipſe began, when the Moon appeared of a very red colour, eſpecially towards that part of the Limb where the direct Raies left it, which was at the *Mare Criſium*, which is oppoſite to *Grimaldi*. Now the Skie being ſomewhat clearer, it being before hazy, with the Teleſcope I began to diſcover a great number of ſmall *Stars* about the *Moon*, which appeared yet much more conſpicuous, after I had taken off the apperture from the Object-glaſs, and amongſt the reſt, one ſeemed very conſpicuous, and lay in the way of the *Moon*, which I diligently watched and obſerved, that it was juſt covered by the *Moon* at $6^h. 47'. 30''$. the *Moon* firſt covering it with that part of it which

which was almoſt perpendicularly under the centre of the *Moon*.

About three quarters of an hour after the total immerſion, the body of the *Moon* was exceeding dark, and almoſt unperceivable, being then near the centre of the *Umbra*, and afterwards the Eaſtermoſt or foremoſt part of the Limb of the *Moon* began to be inlightned, whereas before the Weſtermoſt Limb had been the brighteſt. This was alſo very notable, that that part of the *Moon* that was towards the North-Pole, a pretty while before the emerſion of the *Moon* out of the total Eclipſe, and even till the very emerſion, and ſomewhat after too, appeared inlightned with a much brisker light than any other part of the body, except that which was next the Limb where the light again entred. From what cauſe this ſhould happen, I know not; poſſibly it might be cauſed by a greater refraction of the Air near the North-Pole of the Earth, and I am much troubled, that I had not taken notice whether the like phenomenon had not happened to the body of the *Moon* before it had paſt the centre of the *Umbra*. It was very manifeſt, that there was a conſiderable quantity of light that kept that Limb of the *Moon* which was next the light, conſpicuous by the Teleſcope all the time of the total Eclipſe; and 'tis very rational to aſcribe it to the Raies of the Sun, refracted by the Air, or atmoſphere of the Earth.

I was very well pleaſed to obſerve the *Moon* to cover ſeveral ſmall *Stars* that lay in its way, but I kept no account of them, but only watched diligently when the *Star* that entred behind the *Moon* at 6. 47. 30. would come out again, which I found it to do at 7. 30'. ſeeing it at the very moment of time that it began to appear again. And it was alſo at the ſame inſtant diſcovered by Sr. *Jonas More*, who was expecting it with another Tube.

At 7. 58. the body of the *Moon* firſt emerged out of the *Umbra* at the ſpot *Grimaldi*, and ſoon after all thoſe ſmall *Stars* that were conſpicuous before about the body of the *Moon*, vaniſhed. However I had, before its firſt emerſion out of the ſhadow, taken a little draught of the ſmall Stars, according to their ſeveral poſitures and magnitudes, only by gueſs,

gueſs, that I might a week after, when the *Moon* was gone farther off, inquire what that Star was that had ſuffered ſo conſpicuous an Eclipſe, and that thereby I might the more certainly determine the true place of the *Sun* and *Moon* at that inſtant, which I found to be that in *Bayer*, touching the Ecliptick, in about 21°.40'. of *Cancer*. The *Umbra* ceaſed wholly at eight of the Clock and five minutes, though the *Penumbra* then poſſeſſed almoſt a third of the *Moons* Diameter, and laſted near half an hour after, before that ſide of the *Moon* was perfectly inlightened like the other.

There was one *Phenomenon* very remarkable, which I took more eſpecial notice of, as ſeeming to me very conſiderable for the determining that controverſie, whether the *Moon* have an atmoſphere or not, like that of the *Earth*? And that was, that after the *Moon* was entred wholly into the *Umbra* of the Earth, that part of the Limb of the *Moon* which was laſt enlightned, continued for a conſiderable while to have a very great brightneſs upon it, which extended on each ſide that part of the Limb, both northwards and ſouthwards, to about a quadrant of the *Moons* Limb, making a repreſentation almoſt of a New *Moon* about a day or two old, and as the body of the *Moon* was immerged deeper into the ſhadow, ſo this brightneſs or light grew fainter and fainter, but ſtill ſeemed to ſpread it ſelf very far upon the Limb of the *Moon* only, and not upon the body thereof. That which was ſpread into the body being much fainter and weaker, and ſeeming (as I before noted) to proceed from the refraction of the Atmoſpheres of the Earth. Nor was this only conſpicuous at the *Moons* entring into the total darkneſs, but as remarkable alſo at the *exitus* thereof out of the ſame, inſomuch that ſome of thoſe Perſons, who at the ſame time viewed the ſame with me, verily believed the *Moon* was not wholly eclipſed ſo ſoon as really it was, nor continued ſo long in that obſcurity, as very viſibly it did by the ſpace of two or three minutes. For I took eſpecial notice when this inlightning of the Limb began again to appear, and I obſerved its increaſe, and ſpreading about the Limb, till the very inſtant that the immediate light of the Sun touched the very extremity of the Limb it

ſelf, which was indeed ſo very briskly bright and ſtrong, that it did not only ſoon make the other light diſappear, but alſo all the Teleſcopical Stars that were near to it, and towards the end alſo many of the more conſpicuous Stars, eſpecially ſuch as were not far from the body of the *Moon*.

Poſtſcript.

I Should have here taken leave of my Reader for this time, but that finding in the *Tranſactions* a paſſage inſerted out of the *French* Journal *de Scavans*, about the invention of applying a *Spring to the Ballance of a Watch, for the regulating the motion thereof*, without at all taking notice that this Invention was *firſt* found out by an *Engliſh*-man, and long *ſince publiſhed to the World*: I muſt beg the Readers patience, whilſt I, in vindication of my own right againſt ſome unhandſome proceedings, do acquaint him with the ſtate of this matter.

About *ſeventeen years ſince*, being very inquiſitive about the *regulating the meaſure of Time*, in order to *find the Longitude*, I did from an Art of Invention, or mechanical *Algebra* (which I was then Maſter of) find out and perfect this contrivance, both as to the Theory and Experimental verification thereof, of which I then diſcourſed to *divers of my Friends*, but concealed the *modus*.

About fifteen years ſince, to wit, in the year 1660, preſently after his Majeſties happy Reſtauration, I was in treaty with ſeveral Perſons of Honour (ſome of which are yet living, though *one* of them is *ſince dead*, but I have ſufficient evidence to produce in his own writing that he was one) for the diſcovery thereof, upon propoſed Articles of encouragement. This I can prove by *undeniable* Witneſſes yet living, and I have ſtill all the Papers, Articles, and Tranſactions of this matter by me, in their own hand-writing.

In

In order to bring this Treaty to pass, I was necessitated to discover something of Invention about *measuring Time*, which was, this way of applying *Springs to the arbor of the Ballance of a Watch, for the regulating the vibrations thereof in all postures.* And this I did, to the end that I might gain somewhat of belief in those Noble Persons (with whom I was to treat) That I had somewhat more than ordinary, and was not one of the heard-of Pretenders to that Invention: which effect it had, and their Treaty with me had finally been concluded for several Thousand pounds, had not the inserting one Clause broke it off, which was, *That if after I had discovered my Inventions about the finding the Longitude by Watches, or otherwise (though in themselves sufficient) They, or any other Person should find a way of improving my Principles, he or they should have the benefit thereof, during the term of the Pattent, and not I.* To which Clause I could no waies agree, knowing 'twas easie to vary my Principles an hundred waies, and 'twas not improbable but that there might be made some addition of conveniency to what I should at first discover, it being *facile Inventis addere.* And judging it most unreasonable to be deprived of the benefit of my Inventions, in themselves sufficient, because others might vary them, or any other ways improve them, of which it was very probable they would have no thought, if they had not the advantage of being instructed by my discovery, it having lain hid some thousands of years already, as indeed the effect hath made evident and certain, there having been nothing done by any body else upon that matter for these fifteen years.

Upon this point our Treaty was broken off, and I concealed the farther discovery of any of the other more considerable parts of my Inventions, for the regulating of *Time-keepers*, as hoping I might find some better opportunity of publishing them together with my way of finding the *Longitude of Places*, for which I hoped to have had some benefit for all the labour, study, and charge I had been at for the perfecting thereof. Upon this I was told, *That I had better have then discovered all, since there were others that would find*

it out within ſix months; to which I anſwered, that *I would try them one ſeven years*; and it is now above twice ſeven, and I do not find it yet found out. Indeed Mr. *Hugens* hath made uſe of that part I diſcovered, and ſomewhat Mr. *Leibnitz* hath hit upon, but both of them are imperfect as I ſhall hereafter ſhew.

'Tis true, I was alarum'd by one of thoſe Perſons about two years after that, who told me, *That he had news that the* Longitude *was found out by a Perſon of Honour, by a way of carrying* Mr. Hugens's *Pendulum-Clock, at Sea, by the help of a Ball and Socket, hung to the underſide of the Deck of a Ship.* But having a deſcription of it, I preſently told that Perſon, That *that Invention would do mine no harm*; and indeed we experimentally found it uſeleſs to that effect not long after, upon a trial made of carrying the ſaid Clocks off to Sea in one of His Majeſties *Pleaſure-Boats*, in the year 1662.

The Invention indeed in it ſelf was ingenious, and did much more than what Mr. *Hugens* did expect, as I was then informed by the Right Honourable the Earl of *Kincardine*, the Author and perfecter of that part of the Invention. But wanting a little addition (which I concealed, and Mr. *Hugens* hath not got yet that I hear of) it failed of the effect that was expected. Notwithſtanding this, it was not long after publiſhed in *Low Dutch*, and preſently after in *Engliſh*; wherein what made for it was related, but what made againſt it was concealed, though they were both equally known.

But on the otherſide, all that I could obtain was a Catalogue of Difficulties, *firſt*, in the doing of it, *ſecondly*, in the bringing it into publick uſe, *thirdly*, in making advantage of it. Difficulties were propounded from the alteration of *Climates*, *Airs*, *heats* and *colds*, temperature of *Springs*, the nature of *Vibrations*, the wearing of *Materials*, the motion of the *Ship*, and divers others. Next, it would be difficult to bring it to uſe, for Sea-men knew their way already to any *Port*, and Men would not be at the unneceſſary charge of the *Apparatus*, and obſervations of the Time could not be well made at Sea, and they would no where be of uſe but in Eaſt

and

and West *India* Voyages, which were so perfectly understood that every Common Sea-man almost knew how to Pilot a Ship thither. And as for making *benefit*, all People lost by such undertakings; much had been talkt about the *Præmiums* for the *Longitude*, but there was never any such thing, no King or State would ever give a farthing for it, and the like; All which I let pass.

At the earnest importunity of a Dear Friend of mine, since deceased, I did, in the year 1664, read several of my first *Cutlerian Lectures* upon that Subject, in the open Hall at *Gresham* Colledge, at which were present, besides a great number of the *Royal Society*, many Strangers unknown to me. I there shewed the ground and reason of that application of *Springs* to the *Ballance* of a Watch, for regulating its motion, and explained briefly the true nature and principle of *Springs*, to shew the Physical and Geometrical ground of them. And I explained above twenty several ways by which *Springs* might be applied to do the same thing, and how the *Vibrations* might be so regulated, as to make their Durations either all equal, or the greater slower or quicker than the less, and that in any proportion assigned. Some of these ways were applicable to lesser Vibrations, others to greater, as of 2, 3, 4, 5, 6. or what number of Revolutions were desired; the models of which I there produced, and I did at the same time shew wherein the aforesaid Sea-Clocks were defective.

All these particulars also were at several other times, at the Publick meetings of the *Royal Society*, discoursed, experimented, and several Models produced. I did also, at the earnest desire of some Friends, in the year 1664 and 1665, cause some of the said Watches to be made, though I was unwilling to add any of the better applications of the *Spring* to them, as waiting a better opportunity for my advantage.

Of all these things the Publisher of the *Transactions* was not ignorant, and I doubt not but Mr. *Hugens* hath had an account, at least he might have read so much of it in the History of the *Royal Society* as was enough to have given him notice

notice of it, for *page* 247 of that Hiſtory, amongſt other Experimented Inventions, there are recounted ſeveral new ways of *Pendulum Watches for the Pocket, wherein the motion is regulated by Springs, &c.* The account of the ſeveral ways was given *ſomewhat larger to the Learned Author of that excellent Hiſtory*, though he, as judging it more proper to his deſign, was pleaſed to give only this ſummary account. Mr. *Hugens* might therefore, if he had pleaſed, have mentioned the *firſt Inventer*, *Nam ingenuum eſt fateri*; as he might alſo that of the Circular Pendulum, which is mentioned in the ſame *page* of the aforeſaid Hiſtory.

But though he would not pleaſe to confeſs he knew my publiſhed Invention, yet *I am ſure* he hath manifeſted, that he knows *no more than what I had formerly diſcovered*, he having not in leaſt mentioned the o the Contrivance, which is the principal, and without which the firſt part of the Invention is but lame and imperfect, and doth but limp on one leg, and will ſome time hobble, and ſtumble, and ſtand ſtill. And the ſaid Watches will not be *tres Juſte*, nor ſhew the Longitude at Sea or Land, but, on the contrary, they will be ſubject to moſt Inequalities of motion and carriage, and with many of thoſe motions will be apt to ſtand ſtill, whatever to the contrary is affirmed in the *French Journal*, or in the *Engliſh Tranſactions.*

I forbear now to mention any further the carriage of the Writer of the *Tranſactions* in this Affair, and begging my Readers excuſe for this digreſſion, I ſhall conclude this Tract with a ſhort communication of the general ground of my Invention for *Pocket-Watches*, the number of particular ways being very great, which (that the true Lovers of Art, and they only may have the benefit of) I have ſet down in the *Univerſal* and *Real Character* of the late Reverend Prelate, my Honoured Friend Dr. *John Wilkins*, Lord Biſhop of *Cheſter*, deceaſed. In which I could wiſh, that all things of this nature were communicated, it being a Character and Language ſo truly Philoſophical, and ſo perfectly and thoroughly Methodical, that there ſeemeth to be nothing wanting to make it have the utmoſt perfection, and higheſt Idea of

any

any Character or Language imaginable, as well for Philoſophical as for common and conſtant uſe. And I have this further to deſire of my Reader, who will be at the pains to decipher and underſtand this deſcription, that he would only make uſe of it for his own information, and not communicate the explication thereof to any that hath not had the ſame curioſity with himſelf.

This I do, not ſo much to hinder the ſpreading of this Deſcription here delivered, as to revive, and, if poſſible, bring into uſe and practice that excellent Deſign: It being a Character and Language perfectly free from all manner of ambiguity, and yet the moſt copious, expreſſive and ſignificative of any thing or Notion imaginable, and, which recommends it moſt to common uſe, the moſt eaſie to be underſtood and learnt in the World. *See Table the third.*

To fill the vacancy of the enſuing page, I have here added a *decimate* of the *centeſme* of the Inventions I intend to publiſh, though poſſibly not in the ſame order, but as I can get opportunity and leaſure; moſt of which, I hope, will be as uſeful to Mankind, as they are yet unknown and new.

1. *A way of Regulating all ſorts of* Watches *or* Time-keepers, *ſo as to make any way to equalize, if not exceed the* Pendulum-Clocks *now uſed.*

2. *The true Mathematical and Mechanichal form of all manner of* Arches *for Building, with the true butment neceſſary to each of them.* A Problem which no *Architectonick* Writer hath ever yet attempted, much leſs performed. abccc ddeeeee f gg iiiiiii llmmmmnnnnnoopr r ssstttttttuuuuuuuuux.

3. *The true Theory of* Elaſticity *or* Springineſs, *and a particular Explication thereof in ſeveral Subjects in which it is to be found: And the way of computing the velocity of Bodies moved by them.* ceiiinosssttuu.

4. *A very plain and practical way of counterpoiſing Liquors, of great uſe in* Hydraulicks Diſcovered.

5. *A new ſort of Object-Glaſſes for* Teleſcopes *and* Microſcopes, *much outdoing any yet uſed.* Diſcovered.

6. *A*

6. *A new* Seleniſcope, *eaſie enough to be made and uſed, whereby the ſmalleſt inequality of the Moons ſurface and limb may be moſt plainly diſtinguiſhed.* Diſcovered.

7. *A new ſort of* Horizontal Sayls *for a* Mill, *performing the moſt that any Horizontal Sayls of that bigneſs are capable of; and the various uſe of that principle on divers other occaſions.* Diſcovered.

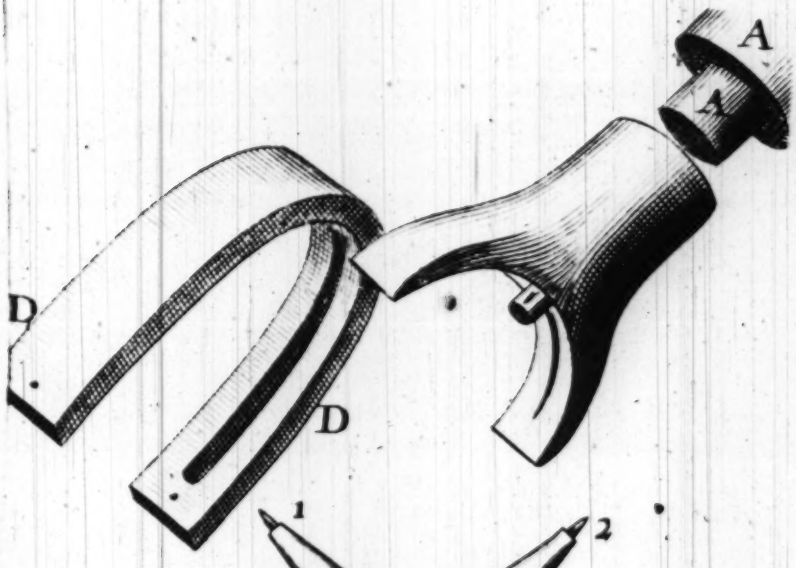
8. *A new way of* Poſt-Charriot *for travelling far, without much wearying Horſe or Rider.* Diſcovered.

9. *A new ſort of* Philoſophical-Scales, *of great uſe in Experimental Philoſophy.* c d e i i n n o o p s s s t t u u.

10. *A new Invention in* Mechanicks *of prodigious uſe, exceeding the* chimera's *of perpetual motions for ſeveral uſes.* a a a æ b c c d d e e e e e e g i i i l m m m n n o o p p q r r r r s t t t u u u u u u.

a a e f f h i i i i l l n r r s s t u u.

FINIS.



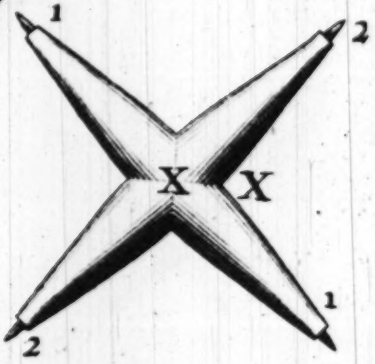
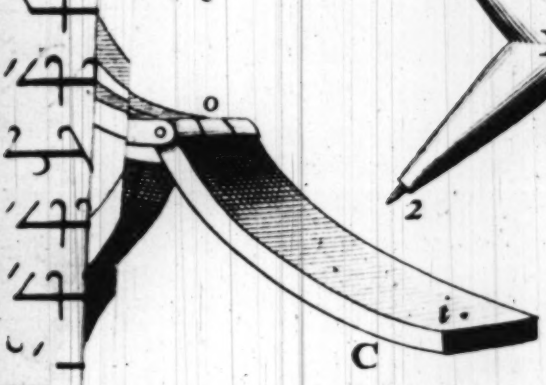
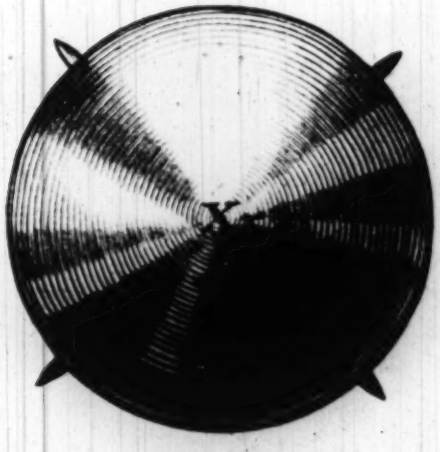



Fig. 9.